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PRELIMINARY ASSESSMENT OF ECOLOGICAL STATUS OF PLANT SPECIES IN THREE SOUTH AFRICAN VELD TYPES †

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ABSTRACT

A method of ordering plant species by their ecological status, known as Index Iteration, was applied to data from three South African veld types. The raw data consisted of wheel-point analyses from the Bankenveld and the *Cymbopogon-Themeda* Veld, and of density and frequency values from the Valley Bushveld. As the data were not originally collected for this kind of treatment, the results are necessarily tentative. However, it is concluded that the method shows promise as a tool for studying changes in ecological status of stands over time and for determining the ecological status of species, providing that certain conditions are adhered to.

INTRODUCTION

In addition to assessing the ecological status of species and stands, the phytosociological ordination studies of the Wisconsin School (Curtis & McIntosh, 1951; Bray & Curtis, 1957; Curtis, 1959; Goff & Cottam, 1967) aim to relate the spatial distribution of species and their importance in stands to variations in the environmental complex. The closeness of the relationship is determined by the degree of correspondence between the quantitative distributions of species and selected environmental factors. The environmental factors may, or may not, be causally related to species behaviour, but the procedure provides a basis for generating hypotheses on plant-environment relationships.

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This paper is concerned with the first aim, namely determining the ecological status of species and stands. Ecological status of stands is taken to mean the relative degree of favourableness of the environment for plant growth and productivity. It is largely, but not entirely, related to favourable moisture conditions. A high status implies very favourable conditions for plant growth, whereas a low status implies unfavourable conditions. Species with high ecological status are those which reach their greatest importance in stands with high ecological status and *vice versa* for species with low ecological status.

An article by Goff & Cottam (1967) describing Index Iteration, a method for arranging species, or stands, along axes of floristic variation, was the stimulus for the present account. They obtained thereby an objectively-determined indication of ecological status. In South Africa very little work has been done in this field, hence the need for trial of Index Iteration under local conditions. Available relative basal cover data from the northern variation of the *Cymbopogon-Themeda* Veld and the western variation of the Bankenveld (Veld Types 48b and 61a, respectively, of Acocks, 1953), and relative density and relative frequency data from the northern variation of the Valley Bushveld (Veld Type 23a) were used.

The ecological status of species is determined by ordering them along an axis, according to their quantitative variation over all stands under consideration. Such an ordination of species can be carried out in at least six different ways (Goff & Cottam, 1967), including the original method of "leading dominants" and the "movable plastic strip" method of Curtis & McIntosh (1951). All methods give fairly similar results (Goff & Cottam, 1967). As Index Iteration has the advantages of speed, objectivity and more efficient use of the information content of the data, it was used in this investigation. In Index Iteration, the Importance Values (q.v.) of species are compared for all possible species pairs over all stands. Those species that attain their highest or lowest Importance Values in the same stands will have a high degree of similarity in their ecological requirements and be situated together along the axis. Those not having similar Importance Values in the same stands will, by the same token, be further removed from each other. The species best adapted to unfavourable conditions is represented by the figure one, at one end of the axis, whereas the species best adapted to favourable conditions is represented by the figure ten at the other end. Together with the scaled values in between, these so-called Species Position Indices (SPI) indicate the relative ecological status of each species. When the Importance Values of species in each stand are weighted by their SPI and these products summed, a Stand Synthetic Index (SSI), formerly called the Compositional Index (CI), is obtained for a stand. The SSI obviously should give an indication of the ecological status of the stand. Reference to environmental features generally indicates that this is so.

REQUIREMENTS FOR DATA COLLECTION

Stands are required to be homogeneous. This is often determined by means of a chi-squared statistical test (Curtis, 1959). Stands are also required to be free of unnatural disturbance and should adequately represent the floristic composition of the vegetation at any particular spot. Stands reasonably objectively selected from the xerosere and the hydrosere are usually separated for interpretive convenience in analysis. In such stands, the Importance Values of the species are assumed to be a measure of their adaptation to the environment. The Importance Value (IV) is usually, but not necessarily, a composite of relative frequency, relative density and relative dominance (cover).

Curtis and co-workers followed what has been termed the mass collection method (see Curtis & McIntosh, 1951). They believed that "... variation in floristic composition is one of the most important characteristics that may be determined in the study of any vegetation ..." (Ibid p. 480). To understand this variation entails the collection of data from a large number of stands (usually 60 or more) within a floristic province. Curtis (1959, p. 600) defines a floristic province as "... a large area with a relatively uniform flora, delimited by a line or zone in which many species reach a common range boundary ...". Obviously the concept of the floristic province is necessary, otherwise the absence of a plant species from a stand may be wrongly construed as "unimportance" of the species in the stand, whereas its absence may be a foregone conclusion due to a major and marked environmental discontinuity.

Ideally, stands representing as much environmental variation as possible within a floristic province should be measured. This will ensure that a truer picture of Species Position Indices is obtained, according to species performance over a wide range of environmental conditions. Obviously then, a localized study, or one representing a narrow range of environmental variation, will not give results that are applicable to a larger area.

The data used in this paper suffer from certain deficiencies as they were originally collected for other purposes. As the mass collection method was not followed strictly, sampling deficiencies also occur. The aims, however, were to obtain preliminary information on the ecological status of major plant species in several veld types, to demonstrate the application and utility of Index Iteration under South African conditions, and to stimulate interest in the method. The inadequacies of the data are considered subordinate to these aims.

PROCEDURE

At each sampling site in the *Cymbopogon-Themeda* Veld and Bankenveld, 2,000 points were taken systematically by means of a wheel-point apparatus (Tidmarsh & Havenga, 1955) to determine the basal cover of grasses, other herbs and small shrubs. Trees and large shrubs were relatively uncommon on the plains, and were not included in the present analysis. Eventually, all species qualifying for inclusion in these two sets of data turned out to be grasses, with the exception of two sedges grouped together as one attribute in the case of the Bankenveld.

Nearly all sampling sites were situated within the degree square 26° to 27° south and 27° to 28° east, roughly in the area between Potchefstroom and Johannesburg. A few sites fell north of this square. Sampling sites were located in the major vegetation type, within one-minute squares, irrespective of the successional stage to which the vegetation belonged, with the proviso that preference would be given to that part of the major vegetation type in best condition. The squares in which sampling sites were located were situated regularly along lines of longitude 15 minutes apart.

Wheel-point surveys were carried out at 52 sites. Only 33, which were deemed to be not unduly disturbed or unnatural, served as stands for the present study. Sixteen were in the *Cymbopogon-Themeda* Veld and 17 in the Bankenveld. The stands included appeared to be homogeneous, according to experienced observation, and were not tested statistically.

Basal cover percentages were converted to a relative base and used in lieu of Importance Values for all species qualifying for the analysis. All species with a presence greater than 56 and 53 per cent in the *Cymbopogon-Themeda* Veld and Bankenveld, respectively, and 33·3 per cent in the combined veld types, were included in the ordination studies.

The third set of data was collected initially for a stand ordination study (Morris, 1967). The study area was the conical hill, Ntshongweni, at the intersection of co-ordinates 29° 51′ south and 30° 43′ east. This hill is about 20 miles west of Durban, Natal, in the valley of the Mlazi River.

The basic sampling units were 60 quadrats of side 30·5 m, each subdivided into 16 square subsamples, the sampling units being located by a process of restricted randomisation. The raw data consisted of density and local frequency values for trees over one metre tall. Importance Values were calculated for the 29 species with frequencies of over 35 per cent in the 60 quadrats. Relative density (RD) and relative local frequency (RF) values for each species were calculated and Importance Values (IV) for species *i* in each quadrat were calculated as:

$$\mathrm{IV}_i = 2\ \mathrm{RD}_i + \mathrm{RF}_i$$

Twice as much weight was given to density than to frequency, because previous overseas work has indicated that density has a greater influence on Importance Values. Using the above procedure, the sum of the Importance Values for each stand is 300, but for future uniformity with other workers (see Goff & Cottam, 1967) it was scaled to 100.

The computer memory was not large enough to handle all 60 quadrats from the Valley Bushveld at the same time, so 20 quadrats from the south-facing slopes of the hill and 22 from the north-facing slopes were analysed separately.

A programme for Index Iteration, in Fortran IV, has been written for an IBM 1130 digital computer. Copies of the programme are available from the authors.

RESULTS

The preliminary Species Position Indices, determined in the three veld types, are presented in Tables 1 and 2.

The position indices for species calculated from the combined data of the Bankenveld and the *Cymbopogon-Themeda* Veld differed quite considerably in value, but to a lesser extent in position, from those calculated for each veld

TABLE 1

Preliminary Species Position Indices (SPI) for the western variation of the Bankenveld (B) and northern variation of the *Cymbopogon-Themeda* Veld (CT)

Species	SPI (nearest 0·5)		
	B + CT	B	CT
Cymbopogon excavatus	3·5	—	1·0
Andropogon amplectens	8·0	8·5	1·5
Triraphis andropogonoides	4·0	1·5	—
Aristida canescens	1·0	—	2·0
Trachypogon spicatus	9·5	10·0	2·0
Brachiaria serrata	6·5	6·0	2·5
Eragrostis atherstonei	4·5	—	—
Eustachys paspaloides	4·5	2·5	—
Aristida congesta	4·0	1·0	3·0
Cynodon dactylon	4·5	—	3·0
Cymbopogon plurinodis	5·0	2·0	4·5
Eragrostis racemosa	9·0	10·0	4·5
Eragrostis chloromelas & E. curvula	6·5	6·0	5·0
Bulbostylis & Fimbristylis *spp.*	—	5·0	—
Digitaria eriantha *var.* stolonifera	6·5	5·0	—
Tristachya rehmannii	7·0	5·5	—
Setaria flabellata	8·0	8·0	6·5
Andropogon schirensis	8·5	7·0	—
Heteropogon contortus	9·0	9·0	7·0
Elyonurus argenteus	9·0	9·5	8·5
Digitaria tricholaenoides	10·0	10·0	—
Themeda triandra	9·5	9·0	10·0

TABLE 2
Species Position Indices (SPI) for 20 quadrats on the south-facing slopes of Ntshongweni and 22 quadrats on the north-facing slopes

South-facing slopes species	SPI (nearest 0·5)	North-facing slopes species	SPI (nearest 0·5)
Acalypha sonderiana	10·0	Canthium inerme	10·0
Dombeya tiliacea	8·0	Heteropyxis natalensis	9·5
Euphorbia tirucalli	8·0	Ziziphus mucronata	9·5
Grewia occidentalis	7·5	Acacia nilotica	9·0
Ochna arborea	7·5	Fagara capensis	9·0
Euclea natalensis	7·5	Cussonia spicata	9·0
Hippobromus pauciflorus	7·5	Acacia robusta	8·5
Canthium inerme	7·0	Rhus pentheri	8·5
Canthium mundianum	7·0	Acacia caffra	8·5
Ehretia rigida	7·0	Dichrostachys cinerea	8·5
Putterlickia verrucosa	7·0	Ochna arborea	8·5
Ziziphus mucronata	7·0	Putterlickia verrucosa	8·5
Fagara capensis	7·0	Dombeya rotundifolia	8·5
Brachylaena elliptica	7·0	Canthium mundianum	8·5
Cussonia spicata	7·0	Maytenus heterophylla	8·5
Euphorbia ingens	7·0	Xeromphis rudis	8·0
Acacia robusta	7·0	Aloe candelabrum	7·5
Heteropyxis natalensis	6·5	Commiphora caryifolia	7·5
Rhus pentheri	6·5	Euclea natalensis	7·5
Maytenus heterophylla	6·5	Euphorbia ingens	7·5
Spirostachys africana	6·5	Ehretia rigida	7·0
Combretum molle	6·5	Grewia occidentalis	7·0
Dichrostachys cinerea	6·5	Brachylaena elliptica	7·0
Dombeya rotundifolia	6·5	Combretum molle	6·5
Commiphora caryifolia	6·5	Hippobromus pauciflorus	6·0
Acacia caffra	6·5	Spirostachys africana	5·5
Acacia nilotica	6·0	Dombeya tiliacea	5·5
Xeromphis rudis	5·5	Acalypha sonderiana	1·5
Aloe candelabrum	1·0	Euphorbia tirucalli	1·0

type separately. The separate treatment of veld types was favoured, in this case, for reasons mentioned in the discussion.

Some species from the Valley Bushveld had very low frequencies within one or other of the two quadrat groups, even though their frequencies over all 60 quadrats were high. For example, *Aloe candelabrum* occurred in only one of the 20 quadrats on the south-facing slopes but had an overall frequency of 48 per cent. Because one requirement for the calculation of SPI is that all species have reasonably high frequencies, the SPI values obtained in this manner must be considered to be very tentative. It was not considered worthwhile reselecting those species with high frequencies in the two quadrat groups and then recomputing the Importance Values and SPI for the purpose of this preliminary paper.

The position indices of species which qualified for inclusion in the computations in the Bankenveld and the *Cymbopogon-Themeda* Veld were weighted by their Importance Values, thereby obtaining a Stand Synthetic Index for each stand. The usual procedure was followed, namely, multiplication of SPI by IV, and summation for the stand. When the Stand Synthetic Indices were compared with an independent subjective assessment of ecological status of stands, arrived at by allotting stands to three groups: low, medium and high status, the agreement was fairly good, particularly in the case of the Bankenveld (Table 3). Stand Synthetic Indices were not calculated for Ntshongweni because a stand ordination of all 60 quadrats had been carried out in a previous study (Morris, 1967). It was anticipated that very little additional information would be obtained by calculating SSI for 20 and 22 of the 60 quadrats separately.

TABLE 3
Ecological status of stands ordinated from lowest to highest

Bankenveld			*Cymbopogon-Themeda* Veld		
Stand No.	SSI(1)	Subjective(2) assessment	Stand No.	SSI(1)	Subjective(2) assessment
12	73·0	L	16	61·0	L
6	76·8	L	24	68·1	L
17	81·6	L	22	70·3	M
21	82·6	M	20	71·1	M
15	84·1	L	28	71·6	L
9	84·8	M	18	72·2	L
8	84·9	M	33	74·0	M
7	85·3	M	23	74·9	M
14	85·6	L	19	75·1	M
11	86·4	M	27	76·8	H
10	87·8	M	31	76·8	H
3	88·7	H	25	76·9	M
4	89·3	H	29	78·6	M
5	89·1	H	26	79·4	M
13	90·9	M	30	80·7	H
1	91·5	H	32	82·9	H
2	92·1	H			

(1) Stand Synthetic Indices
(2) L = Low; M = medium; H = high ecological status

The results presented were obtained by processing the data in the species mode, i.e. Importance Values of species were compared with each other over all stands or quadrats, and the species ordered. Data may also be processed in the stand mode, i.e. Importance Values of species may be compared for stand pairs over all species and the stands ordinated (see Goff & Cottam, 1967). As the data were not specifically gathered for the type of work demonstrated here, and because good environmental data were not available, treatment of data in the stand mode was not carried out for the Bankenveld and *Cymbopogon-Themeda* Veld.

DISCUSSION

Preliminary results

The relative basal cover percentages in the stand by species matrices indicate that *Digitaria tricholaenoides*, *Tristachya rehmannii*, *Triraphis andropogonoides*, *Andropogon schirensis*, *A. amplectens*, *Trachypogon spicatus*, *Eragrostis racemosa* and *Brachiaria serrata* are far more frequent and important in the Bankenveld than in the *Cymbopogon-Themeda* Veld. They are not entirely excluded from the latter (with the possible exception of the first species), but are largely confined to stony outcrops. There are many indications that the Bankenveld has a lower ecological status than the *Cymbopogon-Themeda* Veld. This is implied also by Louw (1951).

In the absence of a specifically planned, and more intensive study, it would be unwise to be dogmatic about the order of ecological status obtained for the species listed in the tables. In general, they conform to what would be expected from field experience. There are a few anomalies. *Cymbopogon* spp. appear to be placed lower than would be expected. Louw (1951, p. 57) rated *Cymbopogon* spp. as occurring high in the plant succession, following on *Themeda triandra*-dominated grassland. Bews (1918) thought the same, saying that they belonged to a stage transitional to forest or else to the hydrosere. Grunow (1965) considered *C. plurinodis* to be a species occurring more frequently in mesophytic than xerophytic or hydrophytic conditions. It is possible that factors like burning or grazing, considered natural in South Africa, would maintain *Cymbopogon* spp. at a lower level of importance than would be expected from uninhibited competition. It is inherent in Index Iteration and similar methods of ordination that under these circumstances the gradient placement of these species would be lowered.

The placement of most other species seems to be borne out by the successional placement mentioned in the literature. The following grasses and sedges are placed in the initial grassland stages as pioneers: *Aristida congesta*, and Aristidas in general, *Cynodon dactylon*, *Eragrostis chloromelas* and other species (Bews, 1918; Adamson, 1938; Louw, 1951; Bayer, 1955), *Bulbostylis* spp. and

Eustachys paspaloides (Bews, 1918). The following grasses are placed in stable grassland as climax grasses or their associates: *Themeda triandra* (Bews, 1918; Adamson, 1938; Louw, 1951; Bayer, 1955), *Elyonurus argenteus* (previous authors and Rose Innes, quoted by Roux, 1954), *Andropogon amplectens*, *A. schirensis*, *Brachiaria serrata*, *Digitaria eriantha*, *D. tricholaenoides*, *Setaria perennis* (and presumably also *S. flabellata*), *Heteropogon contortus* (Bews, 1918), *Trachypogon spicatus* (Rose Innes, quoted by Roux, 1954; Davidson, 1964; Edwards, 1967). Thus, at least the primary separation of pioneer from climax species (low ecological status from high ecological status) is achieved by Index Iteration.

Owing to the computer limitations mentioned previously, the SPI obtained for the Valley Bushveld must be considered very tentative. If the species with low frequencies (e.g. *Aloe candelabrum* on the south-facing slopes) had been omitted, a more useful ordering would possibly have resulted.

The environmental factors affecting SPI on the south-facing slopes are not clear. *Acalypha sonderiana* and *Euphorbia tirucalli*, with high SPI and *Aloe candelabrum* with the lowest SPI are considered to be species with low ecological status. All three are characteristic of dry, shallow soils (see Bews, 1917). *Aloe candelabrum* is a leaf succulent and *Euphorbia tirucalli* a stem succulent of very dry regions (see also Edwards, 1967). However, *Dombeya tiliacea*, *Grewia occidentalis*, *Euclea natalensis* and *Hippobromus pauciflorus* are considered by the authors, and supported by Edwards (1967), to be species of high ecological status, being either locally mesic, stream-bank or forest precursor species. The Species Position Indices on the south-facing slopes are thus difficult to interpret. Species which are considered to have high ecological status are placed next to species which have low status while species at both ends of the axis have low ecological status.

An order which is much easier to interpret and is more informative resulted from analysing 22 quadrats from the north-facing slopes of Ntshongweni. The two species with the lowest SPI are *Acalypha sonderiana* and *Euphorbia tirucalli*. As mentioned above, these species are considered to have low ecological status. The large SPI hiatus between these two species and the others indicates how different they are from the others with respect to ecological status. According to Edwards (1967) and the present authors, the following species, which have high SPI, have high ecological status: *Canthium inerme*, *Heteropyxis natalensis*, *Ziziphus mucronata*, *Fagara capensis* and *Acacia robusta*. Bews (1917) also considered *Ziziphus mucronata* to have a high ecological status. Species with low ecological status, according to Edwards (1967) and the present authors, which have SPI of less than 8·0 include: *Aloe candelabrum*, *Euphorbia ingens*, *Brachylaena elliptica*, *Combretum molle* and *Spirostachys africana*. The last-mentioned species inhabits the very dry bottom of the Tugela Valley (Edwards, 1967). According to the present analysis and Bews (1917), *Ehretia rigida* is accorded low ecological status.

A subjective ordering of these species would alter the positions of some species. *Hippobromus pauciflorus* and *Grewia occidentalis* would be attributed higher ecological status and *Aloe candelabrum* a lower status. Apart from these and a few other discrepancies, agreement between computed SPI and ordering based on field experience is good.

It was also pointed out by Dr. D. Edwards (pers. comm.) that the ordination separates species of base-rich soils from those favouring base-poor soils. Species favouring base-rich soils are *Euphorbia tirucalli*, *Acalypha sonderiana*, *Spirostachys africana*, *Brachylaena elliptica*, *Ehretia rigida* (possibly), *Euphorbia ingens* and *Rhus pentheri*. On the north-facing slopes all these species, with the exception of the last-mentioned species, have low ecological status. Conversely, species favouring base-poor soils have high SPI.

The relationship of SPI to moisture conditions and base-status of the soil discussed above, are only two of the many interrelationships which affect the ordering of species by Index Iteration. The final positioning is the result of averaging out all the relationships. The ordering of species on the south-facing slopes may be difficult to interpret because the gradients oppose one another whereas the major gradients on the north-facing slopes are acting in harmony.

General

Curtis (1959, p. 16; quoting Cain) states that, "the significance of floristic provinces in the study of regional vegetation lies in their influence on the possible floristic composition of the individual communities". It would be unrealistic to expect species of the Boreal element to occur in southwest Wisconsin, because they do not occur anywhere in this area. On the other hand, practically all members of the Prairie and Alleghenian elements do. Any stand of vegetation can, therefore, be taken to have had an equal chance of receiving propagules of all those species. The fact that they have sorted themselves into different combinations must be due to varied historical and environmental factors. Floristic provinces are usually delimited by mapping the distribution ranges of principal species, preferably in conjunction with a knowledge of their abundance at the places for which there is a record (Curtis, 1959).

In Wisconsin, the floristic provinces distinguished correspond with climatic differences. In South Africa, geologic and soil factors, in addition, are often major environmental determinants of plant distribution patterns. In fact, the western variation of the Bankenveld was observed by one of us (J.O.G.) to coincide, within very narrow limits, with the Dolomitic Series of the Transvaal Geological System, while the northern variation of the *Cymbopogon-Themeda* Veld occurs on the Pretoria series of the same system in this area. The latter veld type occurs widely, however, and is certainly not as specific for soil type as the former appears to be.

Many species show marked differences of abundance in the two veld types mentioned above. The occurrence of other species appears to be largely limited to one or other veld type. For this reason, it seems best to treat each as a floristic province separated from the other on the basis of marked soil discontinuities. Separation does not appear justified on climatic grounds, neither do they differ sufficiently to be separated according to floristic origin as both veld types are composed largely of tropical element species of the South African flora.

Although the considerations in defining floristic provinces may seem to be somewhat nebulous, it will probably not be so in practice. Species distributions of relatively large aerial extent are generally fairly readily separable from small ones, whether they be caused by climatic or soil discontinuities. To the authors, it appears that Acocks's (1953) veld types, with some exceptions, may serve satisfactorily as floristic provinces in ordination studies. Some veld types may have to be split, while specific cases come to mind where two or three may be grouped together advantageously. It will undoubtedly be better to process data from an area smaller than the full extent of a floristic province if there is a danger of exceeding the boundary, provided that an adequate range of geographic and other variation is included in the sample. The data collected at Ntshongweni excluded geographic, if not other variation, and cannot be considered representative of the whole Valley Bushveld.

It must be emphasized that Species Position Indices do not necessarily reflect position along the moisture gradient, although this has often been found to be the case. Some other soil factor, for example, may set a limit to the importance which a species can achieve under natural competitive conditions over the whole extent of the floristic province, thereby resulting in a low Species Position Index, or even excluding the species entirely.

The results published in this paper are tentative and applicable only to the variations of veld types mentioned because the data did not come from a wide enough geographic or environmental range of variation. They may be found useful, however, for assessing veld condition trends in the localities concerned. Basal cover data, which are often available for the herbaceous stratum, may be placed on a relative basis and the Stand Synthetic Indices calculated (see Table 3), at intervals of a few years. This will indicate whether the stands concerned are changing to less favourable or more favourable ecological conditions.

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